Human-Powered Orrery

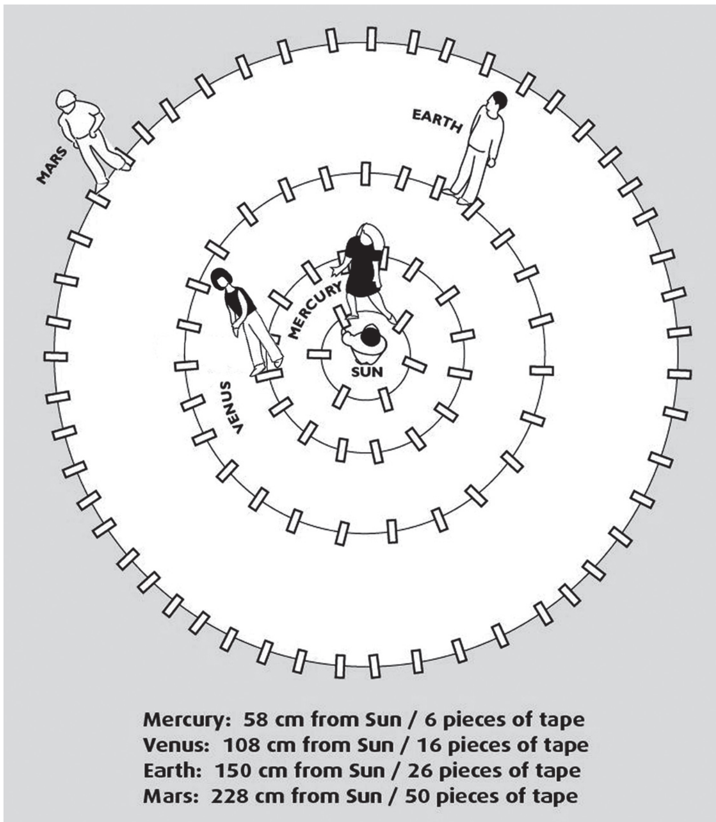
An orrery is a mechanical model of the solar system that illustrates the relative motions and positions of bodies in the solar system. In this activity, you create a human-powered orrery that models the movements of the four inner planets.

Get Ready! Materials and Preparation

- A clear space at least 5 meters (about 17 feet) square
- A 2.5 meter piece of thin rope or string that does not stretch. Tie a large knot at one end of the rope and four more knots along the rope for the scale distance to each planet: 58cm (Mercury), 108cm (Venus), 150cm (Earth) and 228cm (Mars).
- Several rolls of masking or painter's tape (indoors) or chalk (outdoors)
- An overhead transparency of the outer planet's orbits
- 26 people are required for the orrery; if needed, recruit additional people.

GO! Setting Up and Running the Orrery

1. ***Define an Orrery:*** Explain that an orrery is a scale model showing positions and motions of planets, and that the class will make a human powered orrery, one-hundred billionth the size of the actual solar system. The sizes of the planets' orbits are to scale, but the sizes of the planets and the Sun are not to scale. [Optional: Make scale models of Sun (13.9 mm), Mercury (0.05mm), Venus (0.12mm), Earth (0.13mm), Mars (0.07mm)]
2. ***Position the Sun:*** Have students stand in a circle. In the center, mark an X with tape or chalk as the Sun's position. Ask a student to stand on the X.
3. ***Mercury's Orbit.*** Select 6 students to mark Mercury's orbit. Give each chalk or a 10 cm piece of tape, and form a circle around the Sun. Show the knotted rope and explain that each knot on the rope is the scale distance of a planet from the Sun. With the Sun student holding the knot at the end of the rope over the central X, hold the first knot at 58 cm, pulling the string taut, and walk in a circle around the Sun. Have the 6 Mercury students space themselves evenly along the orbit and mark their positions with tape or chalk. Then, these students move off to the side.
4. ***Model Mercury's Movement.*** Have a student stand on one mark in Mercury's orbit. Explain that just as the model has a distance scale, it also has a time scale: each tape mark is about 2 Earth weeks. Have the Mercury student step from mark to mark around the Sun in a counterclockwise orbit. Ask "How many weeks does Mercury take to make a complete orbit around the Sun?" [12 Earth weeks.]
5. ***Venus's Orbit.*** Choose a different student to represent the Sun and have 16 students form a circle that is larger than Mercury's orbit. With the Sun student holding onto the knot at the end of the rope over the X, hold the second knot at 108 cm, and walk in a circle around the Sun. Ask the 16 Venus students to space themselves evenly along the orbital path and mark their positions with tape or chalk.
6. ***Compare Mercury and Venus.*** Ask the students to compare the orbits. [Venus's marks are closer together than Mercury's.] Choose two students to represent Mercury and Venus. Explain that both planets must move according to the same time scale—2-week steps. To synchronize movements, the class claps every "2 weeks." With each clap, Mercury and Venus move one step to the next mark, counterclockwise around the Sun. Start slowly, clapping about once every 2 seconds, then pick up the pace. After a dozen or so claps, stop and ask, "If Mercury and Venus were racing around the Sun, who do you think would win the race?" [Mercury.]
7. ***Earth's Orbit.*** Create the orbit of Earth like you did the orbit of Venus, using the 150 cm radius knot. Have 26 Earth students space themselves evenly on Earth's path, and mark their positions with tape or chalk. Point out that the marks on Earth's orbit are closer together than the marks in Venus's. Ask "Will Earth will move slower or faster than Venus?" [Slower.] Then, ask "Will Mars move slower or faster than Earth?" [Slower]
8. ***Mars's Orbit.*** Create the orbit of Mars like you did the orbit of Earth, using the 228 cm radius knot. Have just 25 students space themselves evenly around the Sun and mark their positions with tape or chalk. Then, each student steps to a second position halfway between two marks, and places another mark; total is 50 marks.



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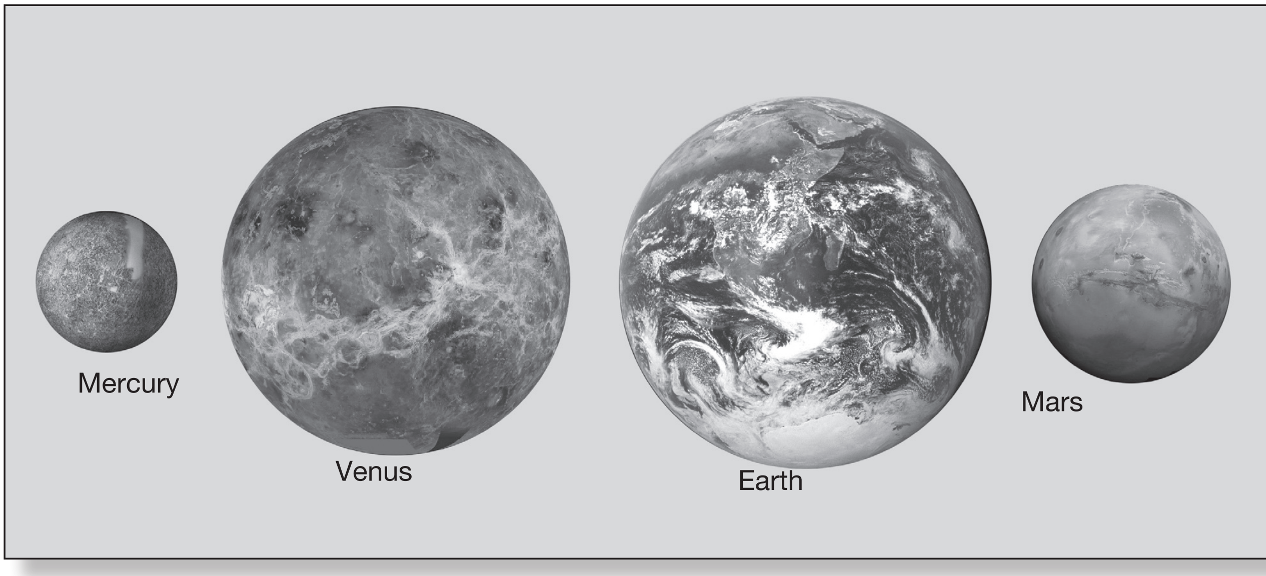

It is difficult to make the sizes of the planets to scale in this model. This illustration shows correct size scale.

9. *Run the Human Powered Orrery for all four planets.* Have 4 students line up as if they are about to begin a race, with one student on each planetary orbit. Tell the class that this is an unusual planetary alignment. Ask, "If the planets were racing to complete their orbits, which planet would you predict will win this race?" [Mercury.] Have everyone clap together chanting "2 weeks" with each clap. Stop after 26 claps when Earth has made one full orbit around the Sun. Ask the class how many weeks have passed. [52 weeks, or 1 year.] Ask students to describe the progress of the other planets and how much time has gone by for them. Re-run the orrery with different students to make sure that everyone participates. Solicit comments and observations from students as they observe the model in action.

10. *What Does the Orrery Show Us?*
Questions about planetary motion:

a. "Is it is the length of the planet's orbit, or the planet's speed that makes the difference in the time for one complete orbit?" [Both.]

b. "What does the term "year length" mean?" [Time for one complete orbit around the Sun.] "Which planet has the shortest year length?" [Mercury] "Which planet has the longest year length?" [Mars]

c. "Is there a relationship between the distance from the Sun and their year lengths?" [The farther from the Sun, the longer the year length.] "Why do planets closer to the Sun have shorter year lengths?" [Shorter orbits and faster speeds.]

d. "How would the movements of the planets appear to someone standing in the position of the Sun?" [The planets appear to move in an organized and orderly manner around the Sun. The viewer sees a consistent pattern in the motion of the planets.]

e. "How do the movements of the planets appear to someone on the Earth?" [Since Earth is not in the center of the solar system and is in motion, the movements of the planets seem complex to an observer on Earth. The planets appear to wander about in different directions and speeds.] Explain that the word planet comes from an ancient Greek word that means "wanderer."

11. *How Good is the Model?* Conclude by having teams list the accuracies and inaccuracies of the orrery.

Some things the model showed accurately:

- All of the planets orbit the Sun in the same direction.
- All of the planets' orbits are in the same plane.
- The orbits are all close to circular.
- The inner planets move faster and have shorter orbits than the outer planets.

Some things the model showed inaccurately:

- The sizes of the planets are not to scale.
- The planets do not spin.

Optional: Have students make predictions about the year lengths and speeds of the outer planets. Then discuss this chart.

Planet	Earth Weeks	Earth Years	Orbital Speed (km/s)
Mercury	12	0.2	48
Venus	32	0.6	35
Earth	52	1	30
Mars	96	1.9	24
Jupiter	308	12	13
Saturn	766	29	10
Uranus	2,184	84	7
Neptune	4,290	165	5

See latest version of Human Orrery at http://kepler.nasa.gov/education/activities/humanorrery/

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